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IS 15585 (2005): Mintered Metal Materials [MTD 25: Powder Metallurgical Materials and Products]

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सिंटरित धातु सामग्रियाँ — विशिष्टियाँ

Indian Standard

SINTERED METAL MATERIALS — SPECIFICATIONS

ICS 77.160

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

August 2005

Price Group 8

Powder Metallurgical Materials and Products Sectional Committee, MTD 25

NATIONAL FOREWORD

This Indian Standard which is identical with ISO 5755 : 2001 'Sintered metal materials — Specifications' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendations of the Powder Metallurgical Materials and Products Sectional Committee and approval of the Metallurgical Engineering Division Council.

In this adopted standard, some terminology and conventions are, however, not identical to those used in Indian Standards. Attention is especially drawn to the following:

a) Whenever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 2738 Sintered metal materials, excluding hardmetals — Permeable sintered metal materials — Determination of density, oil content and open porosity	IS 5642 : 1991 Permeable sintered metal materials — Determination of density, oil content and open porosity (*second revision*)	Identical
ISO 2739 Sintered metal bushes — Determination of radial crushing strength	IS 10385 : 1982 Method for determination of radial crushing strength of sintered metal powder bearings	Technically equivalent
ISO 2740 Sintered metal material, excluding hardmetals — Tensile test pieces	IS 15554 : 2004 Sintered metal materials excluding hardmetals — Tensile test pieces	Identical
ISO 6892 Metallic materials — Tensile testing at ambient temperature	IS 1608 : 1995 Mechanical testing of metals tensile testing (*second revision*)	Technically equivalent

In this adopted standard, reference appears to the following International Standard for which no Indian Standard exists:

ISO 2795	Plain bearings — Sintered bushes — Dimensions and tolerances

In reporting the results of a test or analysis made in accordance with the standards, if the final value, observed or calculated is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

SINTERED METAL MATERIALS — SPECIFICATIONS

1 Scope

This International Standard specifies the requirements for the chemical composition and the mechanical and physical properties of sintered metal materials used for bearings and structural parts.

When selecting powder metallurgical materials, it should be taken into account that the properties depend not only on the chemical composition and density, but also on the production methods. The properties of sintered materials giving satisfactory service in particular applications may not necessarily be the same as those of wrought or cast materials that might otherwise be used. Therefore liaison with prospective suppliers is recommended.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 2738, *Sintered metal materials, excluding hardmetals — Permeable sintered metal materials — Determination of density, oil content and open porosity.*

ISO 2739, *Sintered metal bushes — Determination of radial crushing strength.*

ISO 2740, *Sintered metal material, excluding hardmetals — Tensile test pieces.*

ISO 2795, *Plain bearings — Sintered bushes — Dimensions and tolerances.*

ISO 6892, *Metallic materials — Tensile testing at ambient temperature.*

3 Sampling

Sampling shall be carried out in accordance with the relevant International Standards.

4 Test methods for normative properties

4.1 General

The following test methods shall be used to determine the normative properties given in Tables 1 to 11.

4.2 Chemical analysis

Whenever possible, and always in cases of dispute, the methods of chemical analysis shall be those specified in the relevant International Standards. If no International Standard is available, the method may be agreed upon and specified at the time of enquiry and order.

4.3 Open porosity

The open porosity shall be determined in accordance with ISO 2738.

4.4 Radial crushing strength

The radial crushing strength shall be determined in accordance with ISO 2739.

4.5 Tensile strength

The ultimate tensile strength shall be determined in accordance with ISO 2740 and ISO 6892.

4.6 Tensile yield strength

The yield strength shall be determined in accordance with ISO 2740 and ISO 6892.

4.7 Mechanical properties

4.7.1 General

The mechanical properties given in Tables 1 to 11 were determined on pressed and sintered test pieces at mean chemical composition and are intended as a guide to initial selection of materials (see clause 1). They may also be used as a basis for specifying any special tests that may be indicated on the drawing.

The mechanical properties shall neither be calculated from hardness values, nor be determined on tensile test pieces taken from a component and used for verifying the values given in Tables 1 to 11. If the customer requires that a specified level of mechanical properties be obtained by tests on the component, these shall be agreed with the supplier and shall be stated on the drawing and/or any technical documentation of the customer referred to on the drawing.

4.7.2 Tensile properties

The normative values for yield strength shall be determined in accordance with ISO 6892, using pressed and sintered test pieces made in accordance with ISO 2740. For heat-treated materials, tensile strength and yield strength are approximately equal and in this case tensile strength, determined on machined test pieces according to ISO 2740, is specified.

4.7.3 Radial crushing strength

The radial crushing strength shall be determined in accordance with ISO 2739. The wall thicknesses of test pieces to be used shall be in the range covered by ISO 2795. For test pieces outside this range, the specified radial crushing strength values are different and shall be agreed between customer and supplier.

5 Specifications

The chemical composition and mechanical properties are given in Tables 1 to 11.

The liquid lubricant content of materials for bearings, impregnated with liquid lubricant, shall be not less than 90 % of the measured open porosity.

6 Designations

Designations shall be in accordance with annex A.

Table 1 — Materials for bearings: iron, iron-copper, iron-bronze and iron-carbon-graphite

Parameter	Symbol	Unit	Iron		Iron-copper		Iron-bronze [a]				Iron-carbon-graphite[a]		
			Grade [b]		Grade [b]		Grade [b]				Grade [b]		
Chemical composition			-F-00-K170	-F-00-K220	-F-00C2-K200	-F-00C2-K250	-F-03C36T-K90	-F-03C36T-K120	-F-03C45T-K70	-F-03C45T-K100	-F-03G3-K70	-F-03G3-K80	
C combined [c]		%	< 0,3	< 0,3	< 0,3	< 0,3	< 0,5	< 0,5	< 0,5	< 0,5	< 0,5	< 0,5	Normative values
Cu		%	—	—	1 to 4	1 to 4	34 to 38	34 to 38	43 to 47	43 to 47	—	—	
Fe		%	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	
Sn		%	—	—	—	—	3,5 to 4,5	3,5 to 4,5	4,5 to 5,5	4,5 to 5,5	—	—	
Graphite		%	—	—	—	—	0,3 to 1,0	0,3 to 1,0	< 1,0	< 1,0	2,0 to 3,5	2,0 to 3,5	
Total other elements max.		%	2	2	2	2	2	2	2	2	2	2	
Open porosity min.	P	%	22	17	22	17	24	19	24	19	20	13	
Radial crushing strength min.	K	MPa	170	220	200	250	90 to 265	120 to 345	70 to 245	100 to 310	70 to 175	80 to 210	
Density (dry)	ρ	g/cm^3	5,8	6,2	5,8	6,2	5,8	6,2	5,6	6,0	5,6	6,0	d
Coefficient of linear expansion [d]		10^{-6} K^{-1}	12	12	12	12	14	14	14	14	12	12	d

[a] The range of values given for radial crushing strength (K) indicates the necessity to maintain a balance between combined carbon and free graphite.

[b] All materials can be impregnated.

[c] On the basis of iron phase only.

[d] Informative values.

Table 2 — Non-ferrous materials for bearings

Parameter	Symbol	Unit	Bronze			Bronze with graphite			
			Grade [a]			Grade [a]			
Chemical composition			-C-T10-K110	-C-T10-K140	-C-T10-K180	-C-T10G-K90	-C-T10G-K120	-C-T10G-K160	
Cu		%	Balance	Balance	Balance	Balance	Balance	Balance	Normative values
Sn		%	8,5 to 11,0	8,5 to 11,0	8,5 to 11,0	8,5 to 11,0	8,5 to 11,0	8,5 to 11,0	
Graphite		%	—	—	—	0,5 to 2,0	0,5 to 2,0	0,5 to 2,0	
Total other elements max.		%	2	2	2	2	2	2	
Open porosity min.	P		27	22	15	27	22	17	
Radial crushing strength min.	K		110	140	180	90	120	160	
Density (dry)	ρ	g/cm^3	6,1	6,6	7,0	5,9	6,4	6,8	b
Coefficient of linear expansion [b]		10^{-6} K^{-1}	18	18	18	18	18	18	b

[a] All materials can be impregnated.

[b] Informative values.

Table 3 — Ferrous materials for structural parts: iron and carbon steel

Parameter	Symbol	Unit	Iron			Carbon steel								
			Grade			Grade								
			-F-00-100	-F-00-120	-F-00-140	-F-05-140	-F-05-170	-F-05-340H [a]	-F-05-480H [a]	-F-08-210	-F-08-240	-F-08-450H [b]	-F-08-550H [b]	
Chemical composition														
C combined		%	< 0,3	< 0,3	< 0,3	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,6 to 0,9	0,6 to 0,9	0,6 to 0,9	0,6 to 0,9	Normative values
Cu		%	—	—	—	—	—	—	—	—	—	—	—	
Fe		%	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	
Total other elements max.		%	2	2	2	2	2	2	2	2	2	2	2	
Tensile yield strength min.	$R_{p0,2}$	MPa	100	120	140	140	170			210	240			
Ultimate tensile strength min.	R_m	MPa						340	480			450	550	
Apparent hardness		HV5	62	75	85	90	120	280 HV10	300 HV10	120	140	320 HV10	360 HV10	Informative values
		Rockwell	60 HRF	70 HRF	80 HRF	40 HRB	60 HRB	20 HRC	25 HRC	60 HRB	70 HRB	28 HRC	33 HRC	
Density	ρ	g/cm^3	6,7	7,0	7,3	6,6	7,0	6,6	7,0	6,6	7,0	6,6	7,0	
Tensile strength	R_m	MPa	170	210	260	220	275	410	550	290	390	520	620	
Tensile yield strength	$R_{p0,2}$	MPa	120	150	170	160	200	a	a	240	260	c	c	
Elongation	A_{25}	%	3	4	7	1	2	nm [d]	nm [d]	1	1	nm [d]	nm [d]	
Young's Modulus		GPa	120	140	160	115	140	115	140	115	140	115	140	
Poisson's ratio			0,25	0,27	0,28	0,25	0,27	0,25	0,27	0,25	0,27	0,25	0,27	
Unnotched Charpy Impact		J	8	24	47	5	8	4	5	5	7	5	7	
Compressive yield strength	(0,1 %)	MPa	120	125	130	210	225	300	420	290	290	400	550	
Transverse rupture strength		MPa	340	500	660	440	550	720	970	510	690	790	950	
Fatigue limit 90 % survival [e]		MPa	65	80	100	80	105	160	220	120	170	210	260	

NOTE These materials may be supplied with additives to improve machinability. The properties remain unchanged.

[a] Austenitized at 850 °C for 30 min in a protective atmosphere with a 0,5 % carbon potential, oil quenched and tempered at 180 °C for 1 h.

[b] Austenitized at 850 °C for 30 min in a protective atmosphere with a 0,8 % carbon potential, oil quenched and tempered at 180 °C for 1 h.

[c] Tensile strength and tensile yield strength are approximately the same for heat treated materials.

[d] nm = not measurable.

[e] 90 % fatigue endurance limit in rotating bending tests. Machined test pieces in accordance with ISO 3928.

Table 4 — Ferrous materials for structural parts: copper steel and copper-carbon steel

Parameter	Symbol	Unit	Copper steel		Copper-carbon steel								
			Grade		Grade								
			-F-00C2-140	-F-00C2-175	-F-05C2-270	-F-05C2-300	-F-05C2-500H [a]	-F-05C2-620H [a]	-F-08C2-350	-F-08C2-390	-F-08C2-500H [b]	-F-05C2-620H [b]	
Chemical composition													Normative values
C combined		%	< 0,3	< 0,3	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,6 to 0,9	0,6 to 0,9	0,6 to 0,9	0,6 to 0,9	
Cu		%	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	
Fe		%	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	
Total other elements max.		%	2	2	2	2	2	2	2	2	2	2	
Tensile yield strength min.	$R_{p0,2}$	MPa	140	175	270	300	c	c	350	390	c	c	
Ultimate tensile strength min.	R_m	MPa					500	620			500	620	
Apparent hardness		HV5	70	90	115	150	310 HV 10	390 HV 10	140	165	360 HV 10	430 HV 10	Informative values
		Rockwell	26 HRB	39 HRB	57 HRB	68 HRB	27 HRC	36 HRC	70 HRB	78 HRB	33 HRC	40 HRC	
Density	ρ	g/cm^3	6,6	7,0	6,6	7,0	6,6	7,0	6,6	7,0	6,6	7,0	
Tensile strength	R_m	MPa	210	235	325	390	580	690	390	480	570	690	
Tensile yield strength	$R_{p0,2}$	MPa	180	205	300	330	c	c	360	420	c	c	
Elongation	A_{25}	%	2	3	nm [d]	1	nm [d]	nm [d]	nm [d]	nm [d]	nm [d]	nm [d]	
Young's Modulus		GPa	115	140	115	140	115	140	115	140	115	140	
Poisson's ratio			0,25	0,27	0,25	0,27	0,25	0,27	0,25	0,27	0,25	0,27	
Unnotched Charpy Impact		J	7	8	7	10	5	7	7	8	6	6	
Compressive yield strength	(0,1 %)	MPa	160	185	380	400	560	660	450	480	560	690	
Transverse rupture strength		MPa	390	445	620	760	800	930	800	980	830	1 000	
Fatigue limit 90 % survival [e]		MPa	80	89	130	200	220	260	150	200	230	270	
Fatigue limit 50 % survival [f]		MPa			110	160			120	150			

NOTE These materials may be supplied with additives to improve machinability. The properties remain unchanged.

[a] Austenitized at 850 °C for 30 min in a protective atmosphere with a 0,5 % carbon potential, oil quenched and tempered at 180 °C for 1 h.

[b] Austenitized at 850 °C for 30 min in a protective atmosphere with a 0,8 % carbon potential, oil quenched and tempered at 180 °C for 1 h.

[c] Tensile strength and tensile yield strength are approximately the same for heat-treated materials.

[d] nm = not measurable.

[e] 90 % fatigue endurance limit in rotating bending tests. Machined test pieces in accordance with ISO 3928.

[f] 50 % fatigue endurance limit in 4-point plane bending. Non-machined test pieces in accordance with ISO 3928.

Table 5 — Ferrous materials for structural parts: phosphorus steels

Parameter	Symbol	Unit	Phosphorus steel [a]		Phosphorus carbon steel		Copper-phosphorus steel		Copper-phosphorus-carbon steel		
			Grade		Grade		Grade		Grade		
			-F-00P05-180	-F-00P05-210	-F-05P05-270	-F-05P05-320	-F-00C2P-260	-F-00C2P-300	-F-05C2P-320	-F-05C2P-380	
Chemical composition											
C combined		%	< 0,1	< 0,1	0,3 to 0,6	0,3 to 0,6	< 0,3	< 0,3	0,3 to 0,6	0,3 to 0,6	Normative values
Cu		%	—	—	—	—	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	
P		%	0,40 to 0,50	0,40 to 0,50	0,40 to 0,50	0,40 to 0,50	0,40 to 0,50	0,40 to 0,50	0,40 to 0,50	0,40 to 0,50	
Fe		%	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	
Total other elements max.		%	2	2	2	2	2	2	2	2	
Tensile yield strength min.	$R_{p0,2}$	MPa	180	210	270	320	260	300	320	380	
Apparent hardness		HV5	70	120	130	150	120	140	140	160	Informative values
		Rockwell	40 HRB	60 HRB	65 HRB	72 HRB	60 HRB	69 HRB	69 HRB	74 HRB	
Density	ρ	g/cm^3	6,6	7,0	6,6	7,0	6,6	7,0	6,6	7,0	
Tensile strength	R_m	MPa	300	400	400	480	400	500	450	550	
Tensile yield strength	$R_{p0,2}$	MPa	210	240	305	365	300	340	360	400	
Elongation	A_{25}	%	4	9	3	5	3	6	2	3	
Young's Modulus		GPa	115	140	115	140	115	140	115	140	
Poisson's ratio			0,25	0,27	0,25	0,27	0,25	0,27	0,25	0,27	
Unnotched Charpy Impact		J	18	30	9	15					
Transverse rupture strength		MPa	600	900	700	1000			820	1120	
Fatigue limit 50 % survival [b]		MPa	110	140	140	175	130	160	150	180	

[a] Consultation with the supplier is recommended before these materials are used in magnetic applications. Some soft magnetic PM materials are standardized in IEC 60404-8-9.

[b] 50 % fatigue endurance limit in 4-point plane bending. Non-machined test pieces in accordance with ISO 3928.

Table 6 — Ferrous materials for structural parts: nickel steels

Parameter	Symbol	Unit	Nickel steels											
			Grade											
Chemical composition			-F-05N2-140	-F-05N2-180	-F-05N2-550H [a]	-F-05N2-800H [a]	-F-08N2-260	-F-08N2-600H [b]	-F-08N2-900H [b]	-F-05N4-180	-F-05N4-240	-F-05N4-600H [a]	-F-05N4-900H [a]	
C combined		%	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,6 to 0,9	0,6 to 0,9	0,6 to 0,9	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	Normative values
Ni		%	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	1,5 to 2,5	3,5 to 4,5	3,5 to 4,5	3,5 to 4,5	3,5 to 4,5	
Fe		%	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	
Total other elements max.		%	2	2	2	2	2	2	2	2	2	2	2	
Tensile yield strength min.	$R_{p0,2}$	MPa	140	180	c	c	260	c	c	180	240	c	c	
Ultimate tensile strength min.	R_m	MPa			550	800		600	900			600	900	
Apparent hardness		HV5	80	140	330 HV 10	350 HV 10	160	350 HV 10	380 HV 10	107	145	270 HV 10	350 HV 10	Informative values
		Rockwell	44 HRB	62 HRB	23 HRC	31 HRC	74 HRB	26 HRC	35 HRC	53 HRB	71 HRB	21 HRC	31 HRC	
Density	ρ	g/cm^3	6,6	7,0	6,6	7,0	7,0	6,7	7,0	6,6	7,0	6,6	7,0	
Tensile strength	R_m	MPa	280	360	620	900	430	620	1000	285	410	610	930	
Tensile yield strength	$R_{p0,2}$	MPa	170	220	c	c	300	c	c	220	280	c	c	
Elongation	A_{25}	%	1,5	2,5	nm [d]	nm [d]	1,5	nm [d]	nm [d]	1,0	3,0	nm [d]	nm [d]	
Young's Modulus		GPa	115	140	115	140	140	120	140	115	140	115	140	
Poisson's ratio			0,25	0,27	0,25	0,27	0,27	0,25	0,27	0,25	0,27	0,25	0,27	
Unnotched Charpy Impact		J	8	20	5	7	15	5	7	8	20	6	9	
Compressive yield strength	(0,1 %)	MPa	230	270	530	650	350	680	940	240	280	510	710	
Transverse rupture strength		MPa	450	740	830	1200	800	830	1280	500	830	860	1380	
Fatigue limit 90 % survival [e]		MPa	100	130	180	260	150	200	320	120	150	190	290	

[a] Austenitized at 850 °C for 30 min in a protective atmosphere with a 0,5 % carbon potential, oil quenched and tempered at 260 °C for 1 h.

[b] Austenitized at 850 °C for 30 min in a protective atmosphere with a 0,8 % carbon potential, oil quenched and tempered at 260 °C for 1 h.

[c] Tensile strength and tensile yield strength are approximately equal for heat-treated materials.

[d] nm = not measurable.

[e] 90 % fatigue endurance limit in rotating bending tests. Machined test pieces in accordance with ISO 3928.

Table 7 — Ferrous materials for structural parts: diffusion-alloyed nickel-copper-molybdenum steels

Parameter	Symbol	Unit	Nickel-copper-molybdenum steels [a]										
			Grade										
Chemical composition			-FD-05N2C-360	-FD-05N2C-400	-FD-05N2C-440	-FD-05N2C - 950H [b]	-FD-05N2C - 1100H [b]	-FD-05N4C-400	-FD-05N4C-420	-FD-05N4C-450	-FD-05N4C - 930H [b]	-FD-05N4C - 1100H [b]	
C combined		%	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	0,3 to 0,6	Normative values
Ni		%	1,5 to 2,0	1,5 to 2,0	1,5 to 2,0	1,5 to 2,0	1,5 to 2,0	3,5 to 4,5	3,5 to 4,5	3,5 to 4,5	3,5 to 4,5	3,5 to 4,5	
Cu		%	1,0 to 2,0	1,0 to 2,0	1,0 to 2,0	1,0 to 2,0	1,0 to 2,0	1,0 to 2,0	1,0 to 2,0	1,0 to 2,0	1,0 to 2,0	1,0 to 2,0	
Mo		%	0,4 to 0,6	0,4 to 0,6	0,4 to 0,6	0,4 to 0,6	0,4 to 0,6	0,4 to 0,6	0,4 to 0,6	0,4 to 0,6	0,4 to 0,6	0,4 to 0,6	
Fe		%	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	
Total other elements max.		%	2	2	2	2	2	2	2	2	2	2	
Tensile yield strength min.	$R_{p0,2}$	MPa	360	400	440	c	c	400	420	450	c	c	
Ultimate tensile strength min.	R_m	MPa				950	1100				930	1100	
Apparent hardness		HV5	155	180	210	400 HV 10	480 HV 10	170	200	230 HV 10	390 HV 10	460 HV 10	Informative values
		Rockwell	73 HRB	80 HRB	86 HRB	37 HRC	45 HRC	82 HRB	86 HRB	92 HRB	36 HRC	43 HRC	
Density	ρ	g/cm^3	6,9	7,1	7,4	7,1	7,4	6,9	7,1	7,4	7,1	7,4	
Tensile strength [d]	R_m	MPa	540	590	680	1020	1170	650	750	875	1000	1170	
Tensile yield strength [d]	$R_{p0,2}$	MPa	390	420	460	c	c	440	460	485	c	c	
Elongation	A_{25}	%	2	3	4	nm [e]	nm [e]	1	2	3	nm [e]	nm [e]	
Young's Modulus		GPa	135	150	170	150	170	135	150	170	150	170	
Poisson's ratio			0,27	0,27	0,28	0,27	0,28	0,27	0,27	0,28	0,27	0,28	
Unnotched Charpy Impact		J	14	22	38	11	15	21	28	39	10	15	
Compressive yield strength	(0,1 %)	MPa	350	380	430	1 170	1 380	410	440	510	1 060	1 240	
Transverse rupture strength		MPa	1 040	1 200	1 450	1 420	1 650	1 220	1 380	1 630	1 420	1 650	
Fatigue limit 90 % survival [f]		MPa	190	220	260	400	490	200	240	290	350	410	
Fatigue limit 50 % survival [g]		MPa	170	200	240	380	—	190	220	260	—	—	

[e] nm = not measurable.

[a] These materials are produced from diffusion-alloyed powders with the addition of elemental graphite.

[c] Tensile strength and tensile yield strength are approximately equal for heat-treated materials.

[b] Austenitized at 850 °C for 30 min in a protective atmosphere with a 0,5 % carbon potential, oil quenched and tempered at 180 °C for 1 h.

[d] Properties were derived from pressed, sintered and heat treated test pieces (not machined) in accordance with ISO 2740.

[f] 90 % fatigue endurance limit in rotating bending tests. Machined test pieces in accordance with ISO 3928.

[g] 50 % fatigue endurance limit in 4 point plane bending tests. Non machined test pieces in accordance with ISO 3928.

Table 8 — Ferrous materials for structural parts: pre-alloyed nickel-molybdenum-manganese steels

Parameter	Symbol	Unit	Nickel-molybdenum-manganese steels [a]						
			Grade						
Chemical composition			-FL-05M07N-620H [b, c]	-FL-05M07N-830H [b, c]	-FL-05M1-940H [c, d]	-FL-05M1-1120H [c, d]	-FL-05N2M-650H [c, e]	-FL-05N2M-860H [c, e]	
C Combined		%	0,4 to 0,7	0,4 to 0,7	0,4 to 0,7	0,4 to 0,7	0,4 to 0,7	0,4 to 0,7	Normative values
Ni		%	0,4 to 0,5	0,4 to 0,5	—	—	1,75 to 1,90	1,75 to 1,90	
Mo		%	0,55 to 0,85	0,55 to 0,85	0,75 to 0,95	0,75 to 0,95	0,50 to 0,85	0,50 to 0,85	
Mn		%	0,2 to 0,5	0,2 to 0,5	0,10 to 0,25	0,10 to 0,25	0,1 to 0,6	0,1 to 0,6	
Fe		%	Balance	Balance	Balance	Balance	Balance	Balance	
Total other elements max.		%	2	2	2	2	2	2	
Tensile yield strength min.	$R_{p0,2}$	MPa	f	f	f	f	f	f	
Ultimate tensile strength min.	R_m	MPa	620	830	940	1 120	650	860	
Apparent hardness		HV10	340	380	350	380	320	380	Informative values
		Rockwell	30 HRC	36 HRC	32 HRC	36 HRC	28 HRC	35 HRC	
Density	ρ	g/cm^3	6,7	7,0	7,0	7,2	6,7	7,0	
Tensile strength [g]	R_m	MPa	690	900	1 020	1 190	720	930	
Elongation [g]	A_{25}	%	nm [h]	nm [h]	nm [h]	nm [h]	nm [h]	nm [h]	
Young's Modulus		GPa	120	140	140	155	120	140	
Poisson's ratio			0,25	0,27	0,27	0,27	0,25	0,27	
Unnotched Charpy Impact		J	8	11	10	15	7	12	
Compressive yield strength	(0,1 %)	MPa	650	970	1 140	1 270	750	1 000	
Transverse rupture strength		MPa	1 020	1 280	1 480	1 750	1 100	1 390	
Fatigue limit 90 % survival [i]		MPa	240	300	310	360	250	330	

[a] These materials are produced from pre-alloyed powders with the addition of elemental graphite.

[b] Pre-alloy base powder with a nominal composition 0,45 % Ni, 0,7 % Mo, 0,35 % Mn, balance Fe.

[c] Austenitized for 30 min at 850 °C in a protective atmosphere with a 0,6 % carbon potential, oil quenched and tempered for 1 h at 180 °C.

[d] Pre-alloy base powder with a nominal composition 0,85 % Mo, 0,2 % Mn, balance Fe.

[e] Pre-alloy base powder with a nominal composition 1,8 % Ni, 0,7 % Mo, 0,3 % Mn, balance Fe.

[f] Tensile strength and tensile yield strength are approximately the same for heat-treated materials.

[g] As heat treated tensile properties are derived from machined test bars in accordance with ISO 2740.

[h] nm = not measurable.

[i] 90 % fatigue endurance limit in rotating bending tests. Machined test pieces in accordance with ISO 3928.

Table 9 — Ferrous materials for structural parts: copper or copper alloy infiltrated steels

Parameter	Symbol	Unit	Copper infiltrated steels				
			Grade				
			-FX-08C10-340	-FX-08C10-760H [a]	-FX-08C20-410	-FX-08C20-620H [a]	
Chemical composition							Normative values
C Combined [b]		%	0,6 to 0,9	0,6 to 0,9	0,6 to 0,9	0,6 to 0,9	
Cu		%	8 to 15	8 to 15	15 to 25	15 to 25	
Fe		%	Balance	Balance	Balance	Balance	
Total other elements max.		%	2	2	2	2	
Tensile yield strength min.	$R_{p0,2}$	MPa	340	c	410	c	
Ultimate tensile strength min	R_m	MPa		760		620	
Apparent hardness		HV5	210	460 HV 10	210	390 HV 10	Informative values
		Rockwell	89 HRB	43 HRC	90 HRB	36 HRC	
Density	ρ	g/cm^3	7,3	7,3	7,3	7,3	
Tensile strength	R_m	MPa	600	830	550	690	
Tensile yield strength	$R_{p0,2}$	MPa	410	c	480	c	
Elongation	A_{25}	%	3	nm [d]	1	nm [d]	
Young's Modulus [e]		GPa	160	160	145	145	
Poisson's ratio [e]			0,28	0,28	0,24	0,24	
Unnotched Charpy Impact		J	14	9	9	7	
Compressive yield strength	(0,1 %)	MPa	490	790	480	510	
Transverse rupture strength		MPa	1 140	1 300	1 080	1 100	
Fatigue limit 90 % survival [f]		MPa	230	280	160	190	

NOTE All data are based on single pass infiltration.

[a] Austenitized at 850 °C for 30 min in a protective atmosphere with a 0,8 % carbon potential, oil quenched and tempered at 180 °C for 1 h.

[b] On the basis of iron phase only.

[c] Tensile strength and tensile yield strength are approximately equal for heat-treated materials.

[d] nm = not measurable.

[e] Values derived from ultrasonic resonance testing.

[f] 90 % fatigue endurance limit in rotating bending tests. Machined test pieces in accordance with ISO 3928.

Table 10 — Ferrous materials for structural parts: austenitic, martensitic and ferritic stainless steels

Parameter	Symbol	Unit	Austenitic							Martensitic	Ferritic			
			Grade							Grade	Grade			
			-FL303-170N [a]	-FL303-260N [b]	-FL304-210N [a]	-FL304-260N [b]	-FL316-170N [a]	-FL316-260N [b]	-FL316-150 [c]	-FL410-620H [d]	-FL410-140 [e]	-FL430-170 [e]	-FL434-170 [e]	
Type			303	303	304	304	316	316	316 L	410	410 L	430 L	434 L	
Chemical composition														Normative values
Cr		%	17 to 19	17 to 19	18 to 20	18 to 20	16 to 18	16 to 18	16 to 18	11,5 to 13,5	11,5 to 13,5	16 to 18	16 to 18	
Ni		%	8 to 13	8 to 13	8 to 12	8 to 12	10 to 14	10 to 14	10 to 14	—	—	—	—	
Mo		%	—	—	—	—	2 to 3	2 to 3	2 to 3	—	—	—	0,75 to 1,25	
S		%	0,15 to 0,30	0,15 to 0,30	—	—	—	—	—	< 0,03	< 0,03	< 0,03	< 0,03	
C		%	< 0,15	< 0,15	< 0,08	< 0,08	< 0,08	< 0,08	< 0,03	0,10 to 0,25	< 0,03	< 0,03	< 0,03	
N		%	0,2 to 0,6	0,2 to 0,6	0,2 to 0,6	0,2 to 0,6	0,2 to 0,6	0,2 to 0,6	< 0,03	0,2 to 0,6	< 0,03	< 0,03	< 0,03	
Fe		%	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	Balance	
Total other elements max.		%	3	3	3	3	3	3	3	3	3	3	3	
Tensile yield strength min.	$R_{p0,2}$	MPa	170	260	210	260	170	260	150	f	140	170	170	
Ultimate tensile strength min.	R_m	MPa								620 [d]				
Apparent hardness		HV5	120	180	125	140	115	125	75	300 HV 10 [d]	80	80	95	Informative values
		Rockwell	62 HRB	70 HRB	61 HRB	68 HRB	59 HRB	65 HRB	45 HRB	23 HRC [d]	45 HRB	45 HRB	50 HRB	
Density	ρ	g/cm³	6,4	6,9	6,4	6,9	6,4	6,9	6,9	6,5	6,9	7,1	7,0	
Tensile strength	R_m	MPa	270	470	300	480	280	480	390	720	330	340	340	
Tensile yield strength	$R_{p0,2}$	MPa	220	310	260	310	230	310	210	f	180	210	210	
Elongation	A_{25}	%	nm [g]	10	nm [g]	8	nm [g]	13	21	nm [g]	16	20	15	
Young's Modulus		GPa	105	140	105	140	105	140	140	125	165	170	165	
Poisson's ratio			0,25	0,27	0,25	0,27	0,25	0,27	0,27	0,25	0,27	0,27	0,27	
Unnotched Charpy Impact		J	5	47	5	34	7	65	88	3	68	108	88	
Compressive yield strength	(0,1 %)	MPa	260	320	260	320	250	320	220	640	190	230	230	
Transverse rupture strength		MPa	590	nm [g]	nm [g]	nm [g]	nm [g]	nm [g]	nm [g]	780	nm [g]	nm [g]	nm [g]	
Fatigue limit 90 % survival [h]		MPa	90	145	105	160	75	130	115	240	125	170	150	

NOTE 1 The corrosion properties of sintered stainless steel are not necessarily the same as those of solid stainless steels. In general the austenitic materials can be ranked as type 316L being the best followed by 304 and then 303. These as a group are all better than any of the martensitic or ferritic materials. Type 434 is the best of these materials.

NOTE 2 Sintering may also affect corrosion resistance so that grade -FL 316-150 may be more resistant than the grades sintered in nitrogen-containing atmospheres.

NOTE 3 Before using any sintered stainless steel a corrosion test under expected environmental conditions is recommended.

[a] Grades -FL303-170N, -FL304-210N and -FL316-170N sintered in a nitrogen-containing atmosphere e.g. dissociated ammonia at 1 150 °C.

[b] Grades -FL303-260N, -FL304-260N and -FL316-260N sintered in a nitrogen-containing atmosphere e.g. dissociated ammonia at 1 290 °C.

[c] Grade -FL316-150 sintered in a nitrogen-free atmosphere e.g. hydrogen or vacuum backfilled with argon, at 1 290 °C.

[d] Grade FL410-620H sintered in a nitrogen-containing atmosphere e.g. dissociated ammonia, at 1 150 °C, hardened by rapid cooling and tempered at 180 °C for 1 h.

[e] Grades -FL410-140, -FL430-170 and -FL434-170 sintered in a nitrogen-free atmosphere e.g. hydrogen or vacuum backfilled with argon at 1 290 °C.

[f] Tensile strength and tensile yield strength are approximately the same for heat treated materials.

[g] nm = not measurable.

[h] 90 % fatigue endurance limit in rotating bending tests. Machined test pieces in accordance with ISO 3928.

Table 11 — Non-ferrous materials for structural parts: copper based alloys

Parameter	Symbol	Unit	Brass				Bronze	Nickel silver	
			Grade				Grade	Grade	
Chemical composition			-CL-Z20-75	-CL-Z20-80	-CL-Z30-100	-CL-Z30-110	-C-T10-90R [a]	-CL-N18Z-120	
Sn		%	—	—	—	—	8,5 to 11,0	—	Normative values
Zn		%	Balance	Balance	Balance	Balance	—	Balance	
Ni		%	—	—	—	—	—	16 to 20	
Cu		%	77 to 80	77 to 80	68 to 72	68 to 72	Balance	62 to 66	
Total other element max.		%	2	2	2	2	2	2	
Tensile yield strength min.	$R_{p0,2}$	MPa	75	80	100	110	90	120	
Apparent hardness		HV5	50	68	72	84	68	82	Informative values
		Rockwell	73 HRH	82 HRH	84 HRH	92 HRH	82 HRH	90 HRH	
Density	ρ	g/cm^3	7,6	8,0	7,6	8,0	7,2	7,9	
Tensile strength	R_m	MPa	160	240	190	230	150	230	
Tensile yeld strength	$R_{p0,2}$	MPa	90	120	110	130	110	140	
Elongation	A_{25}	%	9	18	14	17	4	11	
Young's Modulus		GPa	85	100	80	90	60	95	
Poisson's ratio (compression)			0,31	0,31	0,31	0,31	0,31	0,31	
Unnotched Charpy Impact		J	37	61	31	52	5	33	
Compressive yield strength	(0,1 %)	MPa	80	100	120	130	140	170	
Transverse rupture strength		MPa	360	480	430	590	310	500	

[a] The letter R indicates that the material has been repressed.

Annex A
(normative)

Designation system

A.1 Designation of materials

The designation system to be used for sintered metal materials specified in this International Standard is in accordance with ISO/IEC Directives Part 2:1992.

A.2 Description block

The description block shall contain the letter P, denoting powder metallurgical materials.

A.3 Identity block

The identity block shall contain the number of this International Standard, ISO 5755, followed by the individual item block.

A.4 Individual item block

A.4.1 First group

The first group of the individual item block shall consist of one to three capital letters, describing the base metal and ways of adding alloying elements:

— F = Plain iron powder or iron powder with admixed alloying additives

— FD = Iron powder with diffusion-alloyed additives

— FL = Pre-alloyed steel powder

— FX = Copper-infiltrated steel

— C = Copper powder with admixed alloying additives

— CL = Pre-alloyed copper-base powder

— FLD = Pre-alloyed steel powder with diffusion-alloyed additives (this will be used in future revisions)

— FLA = Pre-alloyed steel powder with admixed alloying additives (this will be used in future revisions)

A.4.2 Second group

The second group of the individual item block shall consist of two to six alpha-numeric characters with two digits for the content of dissolved (combined) carbon without a decimal comma (except for copper-based materials and stainless steels) e.g. 03 = 0,3 % C. The third position in this group will be the capital letter assigned to the alloying element with the highest content (if any) followed by the content with one or two digits, e.g. 05 = 0,5 %, 10 = 10 %, 2 = 2,0 % of the element in question. Finally this group ends with the capital letter assigned to the element with the second highest content (if any) but without any indication of the content.

A.4.3 Third group

The third group of the individual item block shall show the value of the minimum yield strength (or tensile strength for heat treated materials) listed as MPa followed, if appropriate, by the letter H indicating heat-treated material.

The individual item block shall start with a hyphen and the groups within the block shall be separated by a hyphen.

A.5 Letters assigned to alloying elements

Letters assigned to alloying elements shall be as follows:

C = Copper; G = Graphite; M = Molybdenum, N = Nickel; P = Phosphorus; T = Tin; Z = Zinc.

A.6 Examples of the designation system

The description block (A.2) and the identity block (A.3) are not used in the tables of materials specifications in this International Standard. They should be used on purchase and technical documentation where any possibility of ambiguity exists.

EXAMPLE 1: **-C-T10-K110** is a copper-based alloy with 10 % added tin, and a radial crushing strength, K, of 110 MPa.

EXAMPLE 2: **-F-08C2-620H** is an iron-based material with 0,8 % carbon, 2 % copper and a minimum tensile strength of 620 MPa in the heat-treated condition.

EXAMPLE 3: **-FD-05N4C-240** is an iron-based alloy with 0,5 % carbon and diffusion-alloyed additions of nickel (4 %) and copper, having a minimum yield strength of 240 MPa.

EXAMPLE 4: **-FL-05N2M-860H** is a pre-alloyed nickel (2 %) and molybdenum steel with 0,5 % carbon and a minimum tensile strength of 860 MPa in the heat-treated condition.

EXAMPLE 5: **-FX-08C20-410** is a copper infiltrated iron-base material with a minimum yield strength of 410 MPa.

EXAMPLE 6: **-FL-304-260N** is a type 304 stainless steel, sintered in a nitrogen-containing atmosphere and having a minimum yield strength of 260 MPa. (Further information on the designation of stainless steels can be found in Table B.10.)

EXAMPLE 7: **ISO 5755-F-05C2-620H** is an example of a purchase order entry showing the International Standard number block in conjunction with the individual item block.

If a description block is used, which is optional, it is nothing more than a P for powder metallurgy and it precedes the above example blocks.

NOTE The materials designated FLA may have elemental additions to the pre-alloyed base powder. In these circumstances the elemental additions will be shown in the third group prior to the minimum yield strength.

As an example -FLA-05M2-N4C2, 600 would be a pre-alloyed nominal 2 % molybdenum steel powder with 0,5 % carbon, to which has been added 4 % nickel and 2 % copper in elemental form, having a minimum yield strength of 600 MPa.

Annex B
(informative)

Microstructures

For the preparation of samples for metallographic examination, reference should be made to ISO/TR 14321.

B.1 Iron, iron-copper, iron-bronze, iron-carbon-graphite materials for bearings — Table 1

In iron-copper bearings, the copper should have melted and flowed into the surrounding small pores. With copper contents greater than 2 % some free copper may be visible but with 2 % or less copper, free copper is generally not present. Bearings should show a minimum of original particle boundaries.

Iron-graphite material should exhibit either free graphite in its microstructure or a free graphite/combined carbon mixture depending on the manufacturing process.

The microstructure of iron-bronze combines the appearances of iron and bronze structures.

B.2 Bronze and bronze with graphite materials for bearings — Table 2

In 90-10 copper-tin bronze bearings, the structure should be alpha bronze with no grey copper-tin compounds and with a minimum of reddish copper-rich areas.

B.3 Iron and carbon steel materials for structural parts — Table 3

The carbon content of a sintered structure can be estimated metallographically from the area fraction of pearlite where 100 % pearlite is equivalent to approximately 0,8 % carbon. Carbon dissolves rapidly in iron and it is therefore unusual to see uncombined carbon after about 5 min sintering at 1 040 °C.

B.4 Copper steel and copper-carbon steel materials for structural parts — Table 4

Admixed copper powder melts at approximately 1 082 °C, then flows between the iron particles and into small pores helping the sintering mechanism. Normally sintered alloys with 2 % or less copper show little or no undissolved copper. At higher percentages the copper will be seen as a separate phase. Copper dissolves in iron but does not penetrate to the centre of the larger iron particles. When copper melts it diffuses or migrates leaving behind fairly large pores that can be easily seen in the microstructure. The combined carbon content may be estimated metallographically from the microstructure as described in B.3.

B.5 Phosphorus steels for structural parts — Table 5

Phosphorus steels with less than 0,1 % carbon have predominantly ferritic structures. When etched in 4 % nital it is possible to distinguish areas with high and low phosphorus content. As carbon is increased, grey or dark areas of fine lamellar pearlite can be seen with light areas of ferrite. By adding copper a network of copper-rich areas can be found in the microstructure. Phosphorus steels are also characterized by well-rounded pores.

B.6 Nickel steels for structural parts — Table 6

The fine nickel powders admixed with iron and graphite do not completely diffuse during ordinary sintering. As-sintered nickel steels show light-coloured austenitic nickel-rich islands with needles of martensite or bainite around their edges. Sintering at elevated temperatures above 1 150 °C will reduce the volume fraction of nickel-rich islands. In the heat-treated condition the nickel-rich islands are light-coloured, austenitic at their centre and with martensitic needles at the edges, (viewed at × 1 000). This heterogeneous structure is normal. The matrix is martensite and, depending on quenching rate, 0 % to 35 % fine pearlite.

B.7 Diffusion-alloyed nickel-copper-molybdenum steels for structural parts — Table 7

These materials are produced from diffusion-alloyed powders with the addition of elemental graphite. These materials produce a heterogeneous microstructure. As-sintered diffusion-alloyed steels show a microstructure similar to the nickel steels in B.6, but with a greater proportion of bainite and martensite. After heat treatment, the structures are similar to those of heat-treated nickel steels.

B.8 Pre-alloyed nickel-molybdenum-manganese steels for structural parts — Table 8

These materials are produced from pre-alloyed steel powders with the addition of elemental graphite. After heat treatment, the pre-alloyed steels exhibit a uniform tempered martensite structure.

B.9 Copper or copper alloy infiltrated steels for structural parts — Table 9

The copper-rich phase can be seen clearly at × 100 to × 1 000. The distribution of the copper phase through the part can be determined, and under infiltrated areas noted, if any exist. Although copper does not fill all the pores, it will fill first the finer interconnected pores by capillary action. The combined carbon content is based on the iron phase only.

B.10 Austenitic, ferritic and martensitic stainless steels for structural parts — Table 10

The -FL303, -FL304 and -FL316 grades are austenitic with some evidence of twin formation. In the 316L type there should be little or no evidence of original particle boundaries, chromium carbides, nitrides or oxides.

The -FL410, -FL430 and -FL434 grades are ferritic in the as-sintered condition. There should be no evidence of prior particle boundaries, oxides or carbides. Even minor residual carbon or nitrogen will appear in the microstructure. The -FL410 heat-treated grade is fully martensitic after normal cooling from the sintering cycle. It also can be hardened separately but, in either case, generally is tempered for optimum toughness.

B.11 Copper based alloys for structural parts — Table 11

Brass, bronze and nickel silver sinter to the point where very few original particle boundaries are observable. In well sintered bronze, the alpha bronze grains have grown from their original fine grain clusters and there is no evidence of blue-grey intermetallic compounds.

Bibliography

[1] ISO 1099, *Metals — Axial load fatigue testing.*

[2] ISO 1143, *Metals — Rotating bar bending fatigue testing.*

[3] ISO 3312, *Sintered metal materials and hardmetals — Determination of Young modulus.*

[4] ISO 3325, *Sintered metal materials, excluding hardmetals — Determination of transverse rupture strength.*

[5] ISO 3928, *Sintered metal materials, excluding hardmetals — Fatigue test pieces.*

[6] ISO 4498, *Sintered metal materials, excluding hardmetals — Determination of apparent hardness and micro-hardness.*

[7] ISO 5754, *Sintered metal materials, excluding hardmetals — Unnotched impact test piece.*

[8] ISO/TR 14321, *Sintered metal materials, excluding hardmetals — Metallographic preparation and examination.*

[9] IEC 60404-8-9, *Magnetic materials — Part 8: Specifications for individual materials — Section 9: Standard specification for sintered soft magnetic materials.*

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This Indian Standard has been developed from Doc : No. MTD 25 (4387).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at New India Printing Press, Khurja, India